Laser Produced Plasma Source for NXE:3300B

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EUVL Symposium

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Outline

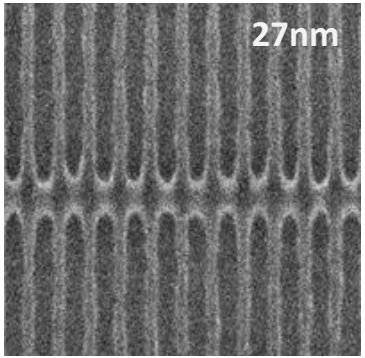
1. NXE:3300 source overview at customer Fabs
2. LPP Development in the Lab
3. EUV power scaling to 250W
4. Summary

EUV status:
Demonstrated >500 wafers per day at customer sites

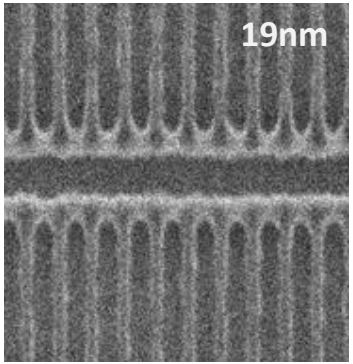
- More than 500 wafers per day demonstrated during endurance tests at 2 customer sites
- 7 NXE:3300B systems qualified and shipped to customers
- 4 more NXE:3300B systems being integrated, one more shipment planned for Q4
- 4th generation NXE system (NXE:3350B) integration ongoing
- EUV cleanroom extension is under construction

NXE:3300B - Good Imaging Performance

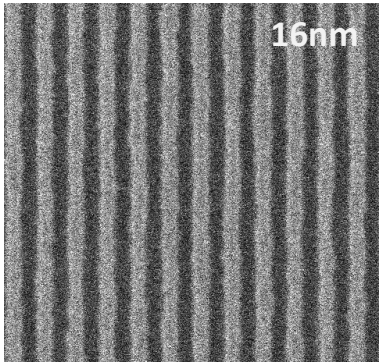
EUV (single expose)



Tip-to-tip

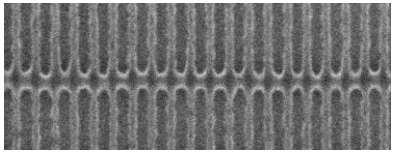


Tip-to-line

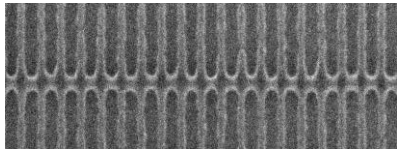


Lines and spaces

Conv. 31 nm

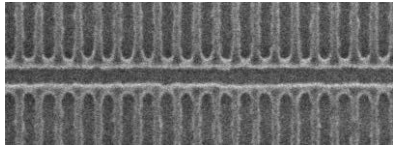


27 nm Quasar

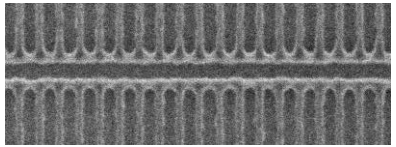


Tip-to-tip

Conv. 20 nm



19 nm Quasar



Tip-to-line

Ref: Presentations of Rudy Peeters and Eelco van Setten

NXE:3300B LPP Source Status in the Fab

40W Operating Node

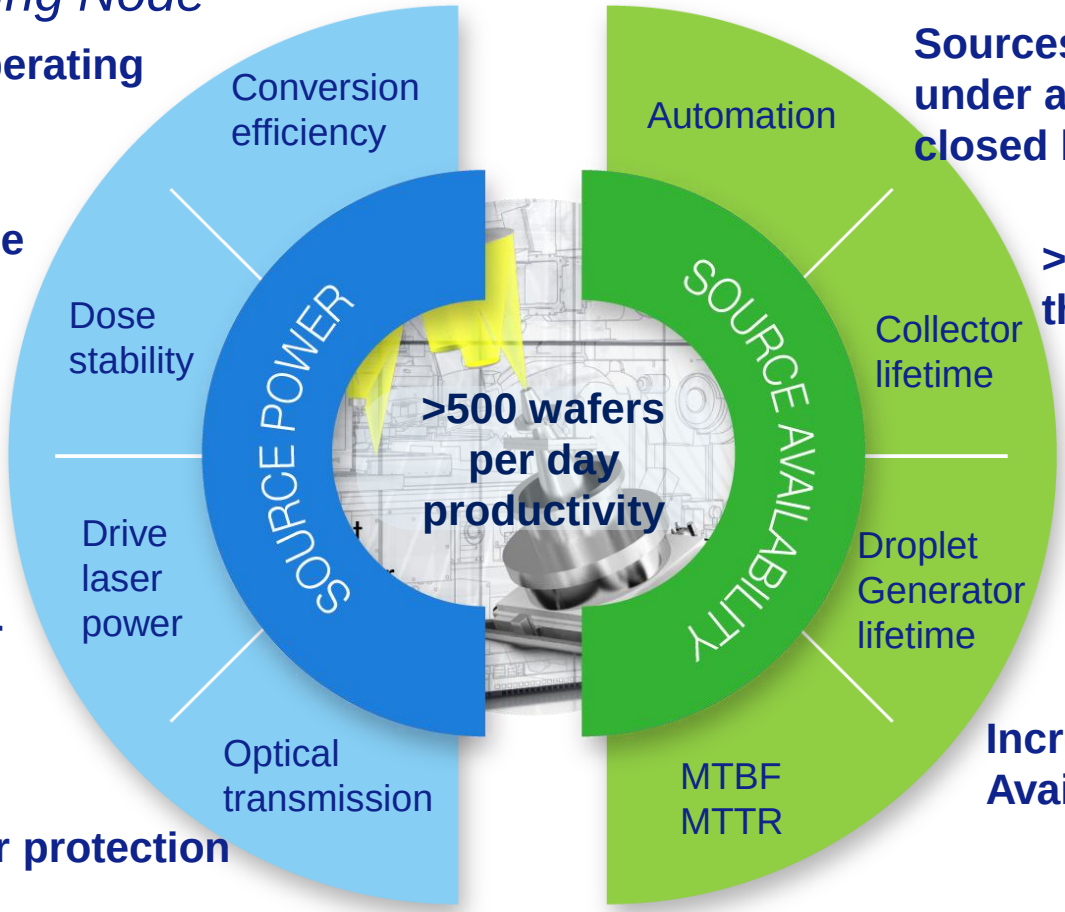
Sources operating with 2% CE

Dose stability / die yield (>99.7%)

Dose margin ~40%

CO2 laser power ~13kW

Collector protection at 40W



Sources operating under automated closed loop control

>50 Gpulses lifetime in the field

Increasing Source Availability

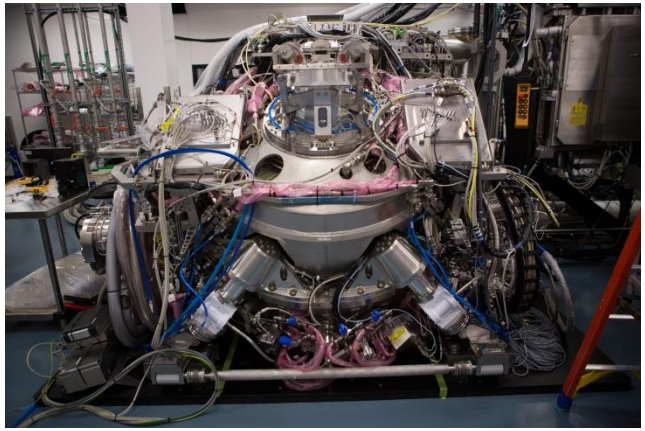
Industrialization of NXE:3300B

NXE:33x0 Source Development Underway

Development and Engineering

Manufacturing

NXE:33x0 Source (Cymer 4)



NXE:3300B Vessel Production

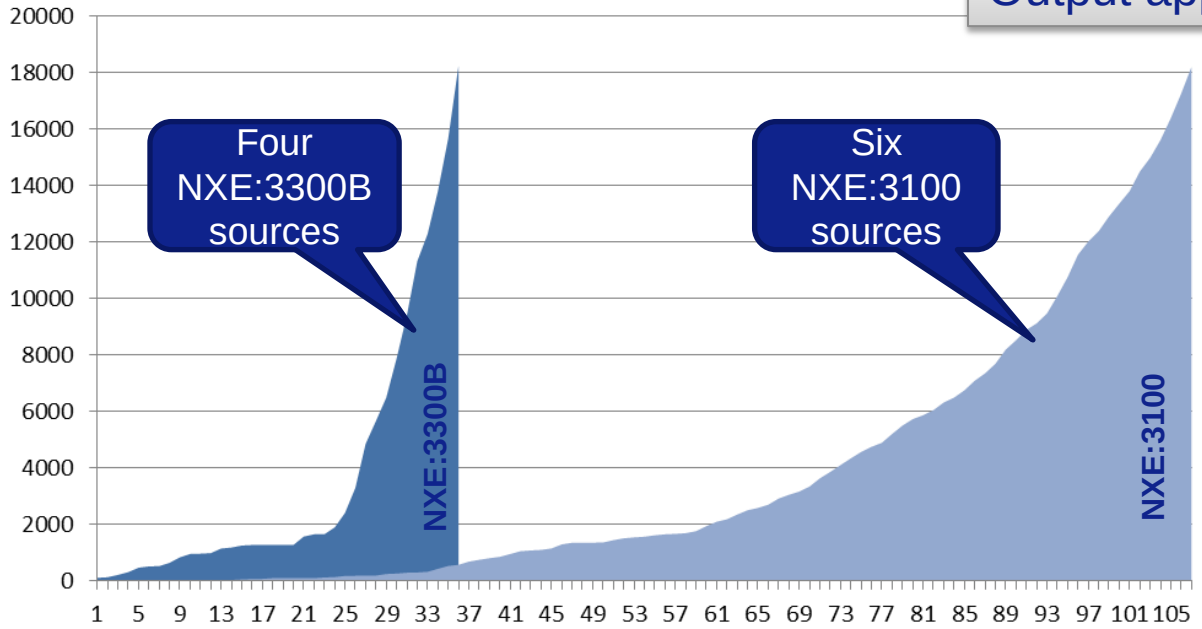
250W Drive Laser (Cymer 4)

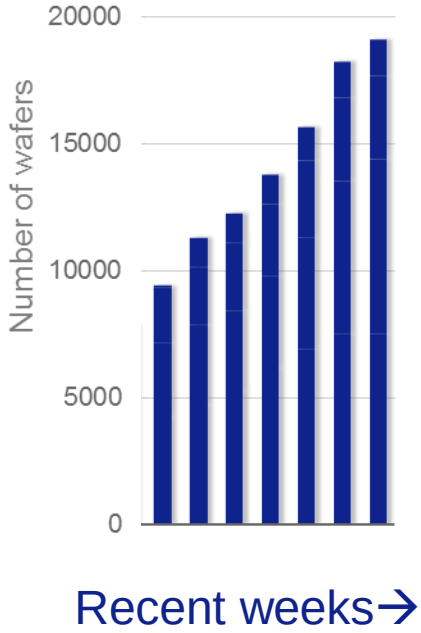
NXE:3300B Training

Produced Wafers on NXE:3300B at Customer Sites

Reaching output in 8 months that took NXE:3100 2 years

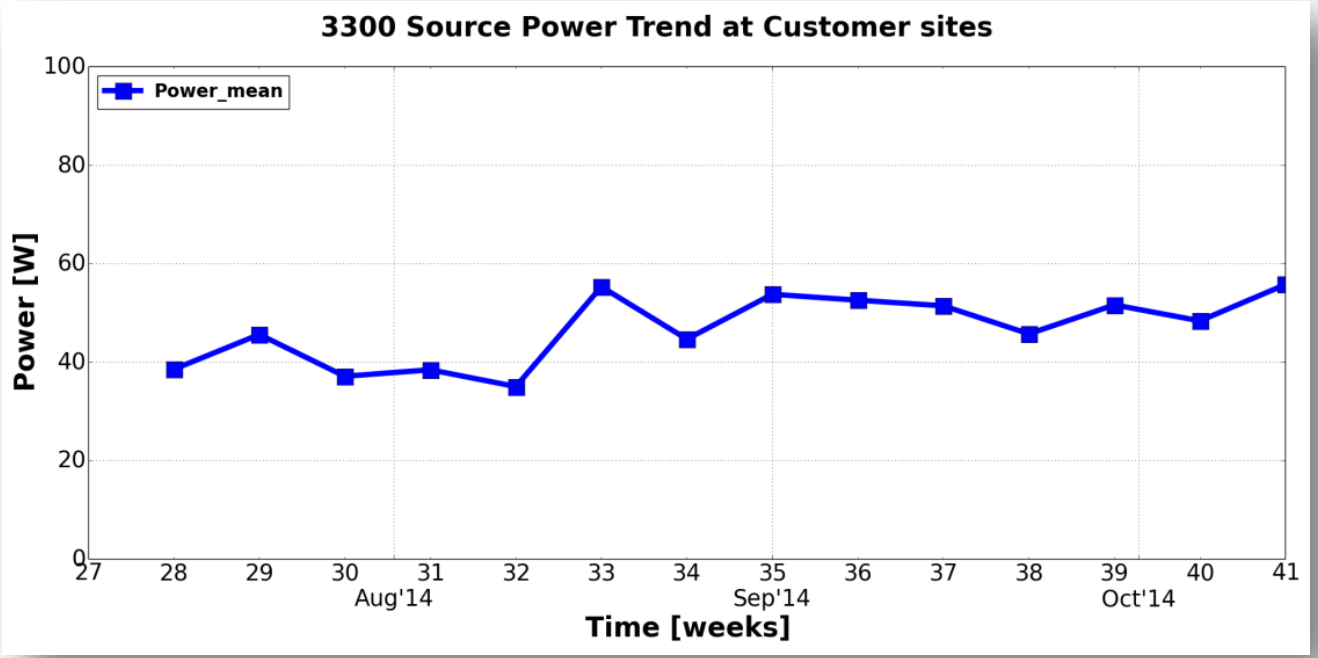
Output approaching 20,000 wafers





NXE:3300B Source Operating for Months at >40W

Stable LPP sources at customers



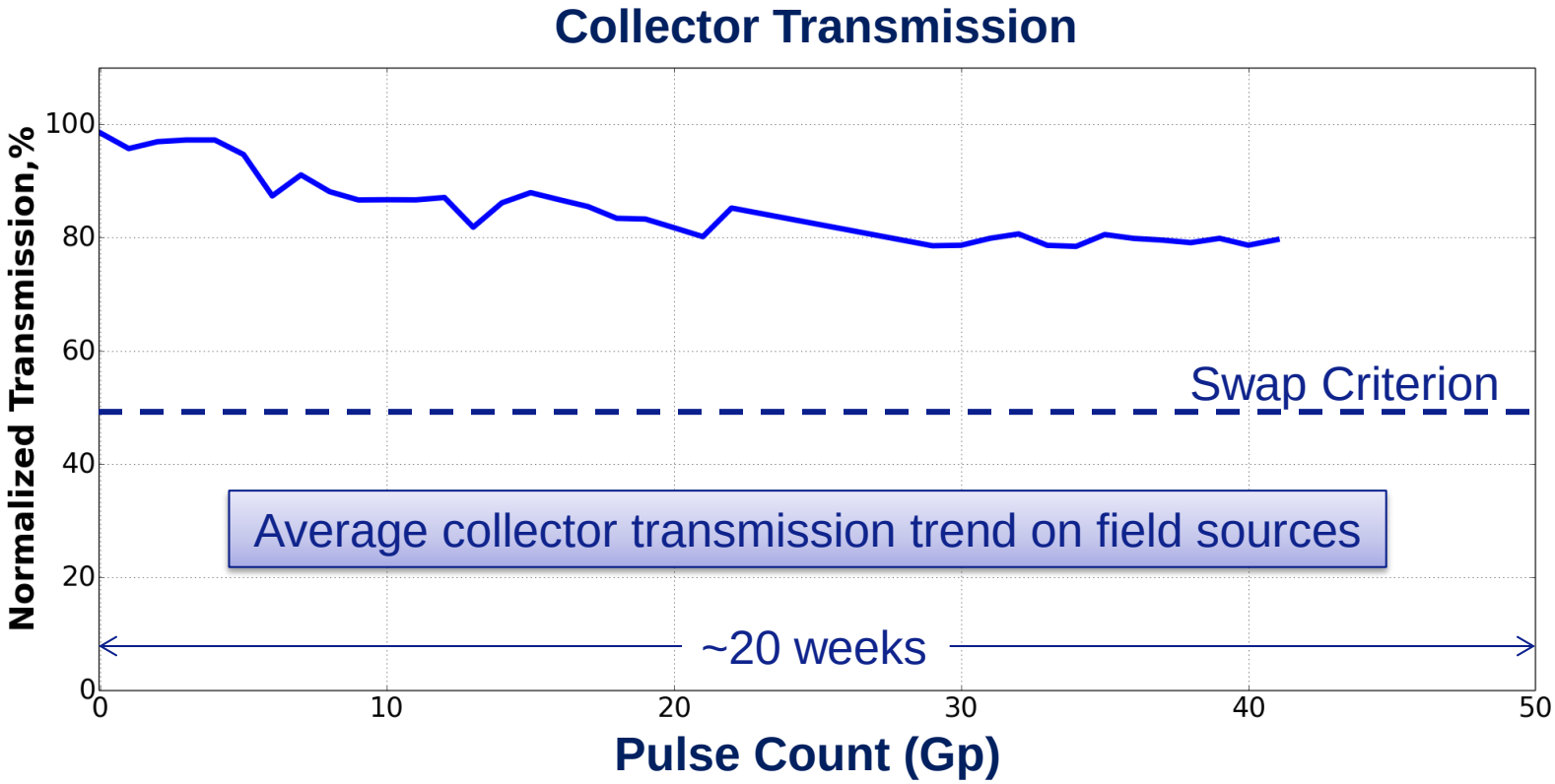
Four Customer Sources

Weekly average power measured in the source

Normalized to clean collector conditions

NXE:3300B Collector Protection on Field Sources

~0.5% EUVR loss per Gigapulse



Current ave. utilization ~2.5Gp per week

Outline

1. NXE:3300B source overview at customer Fabs
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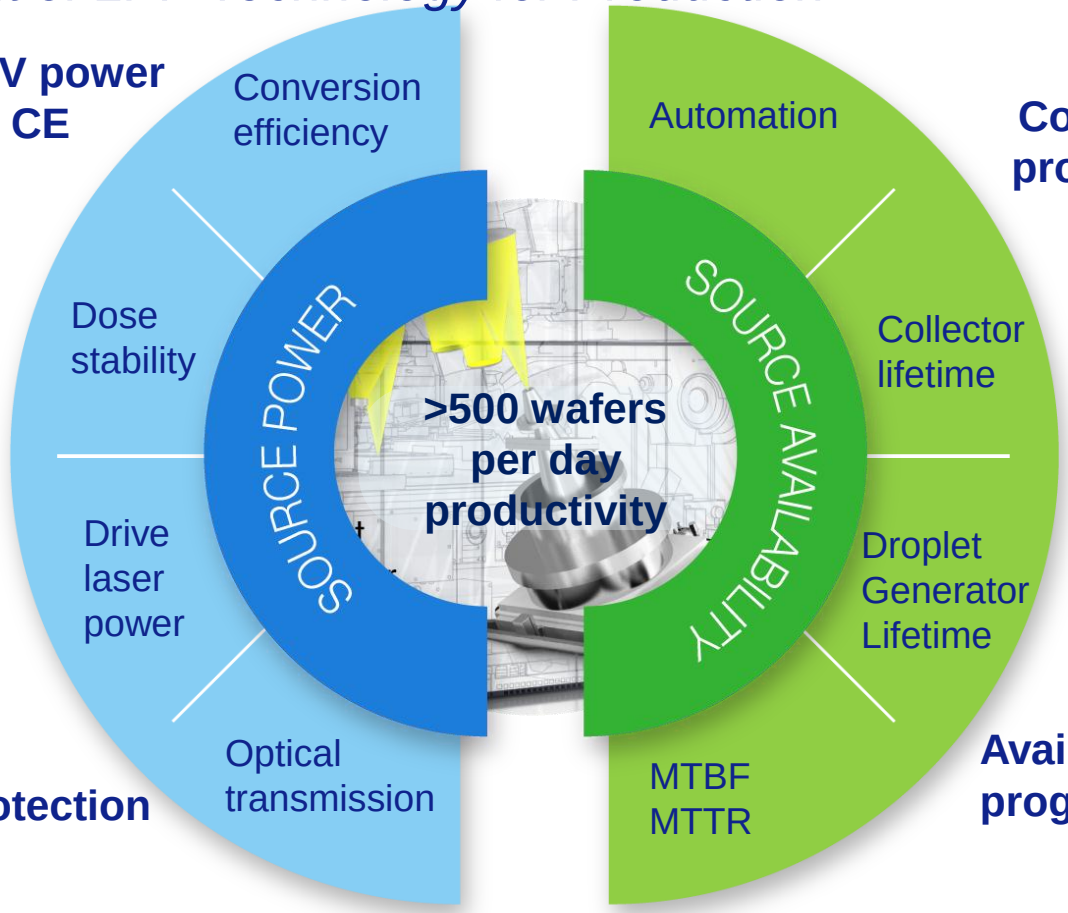
NXE:3300B LPP Source Status in the Lab

Development of LPP Technology for Production



80W EUV power with 3% CE

Dose margin improved to ~25%

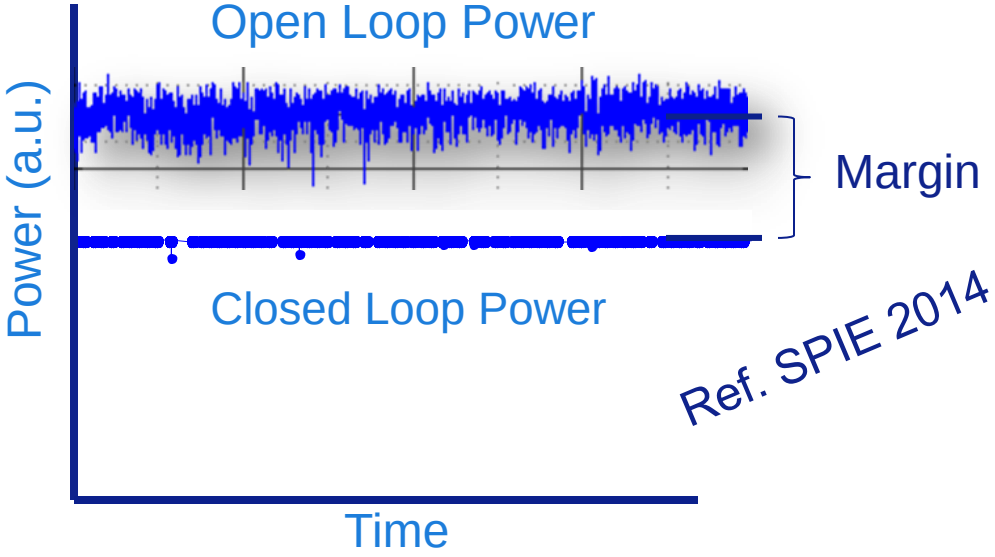
Collector protection at 80W

Collector lifetime projected to >100 Giga pulses

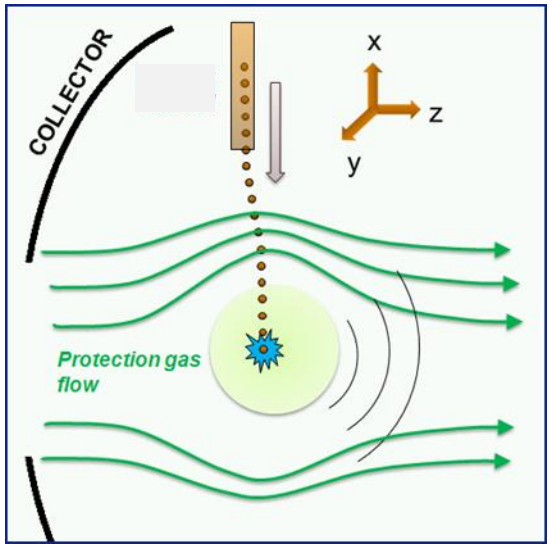
In-situ collector cleaning

Availability program

Def: Dose Margin: lost potential used to stabilize the output power



Ref. SPIE 2014



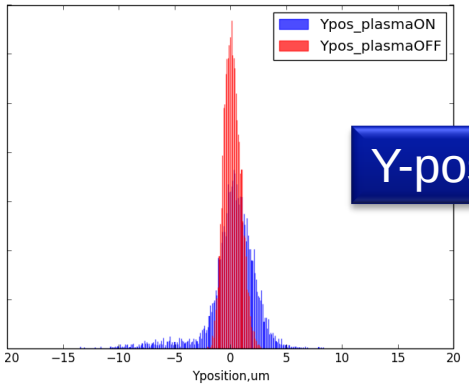
- Much of the lost potential can be recovered with advanced control

- Physical forces distort droplet trajectories causing energy instability

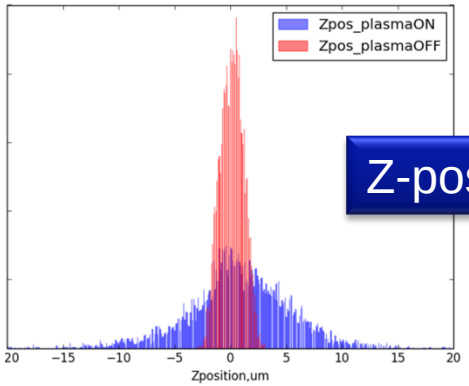
Local Force Compensation (LFC) Controls

Stabilizes dose by compensating for forces on droplets

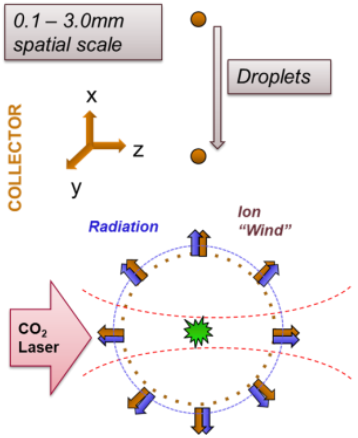
Droplet Position Stability with/without plasma

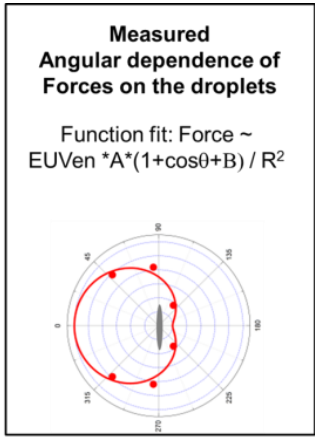


Y-position

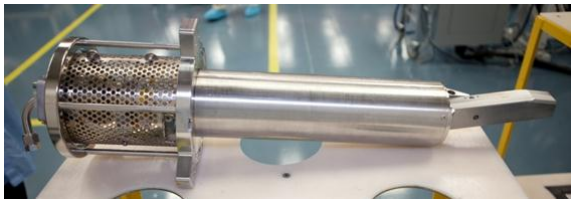


Z-position





Forces on Droplets



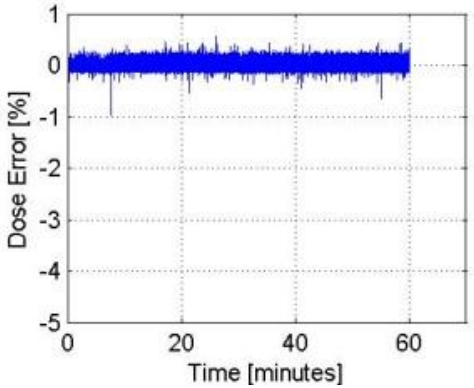
Droplet Generator

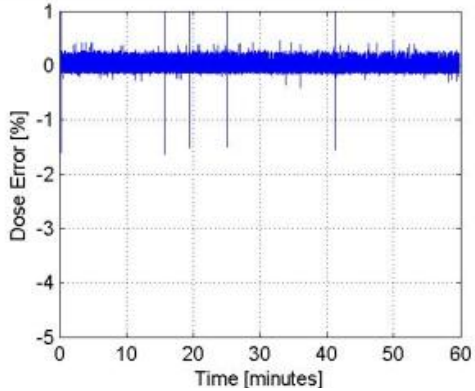
NXE:3300B 80W Source Power Demonstrations

Multiple Runs on Lab Sources

In the Lab (@ASML)

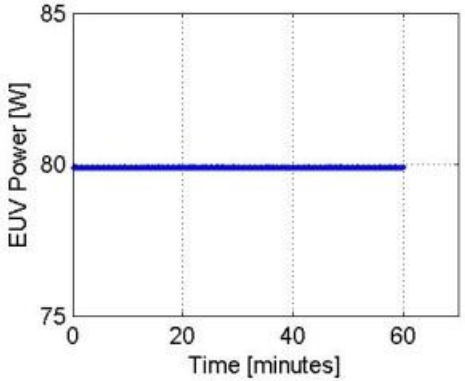
Dose Error

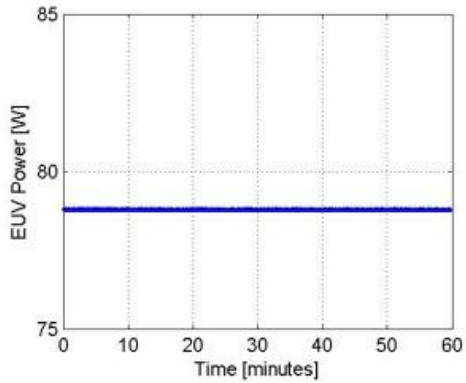




<0.5%
Meets requirement of <1.0% 3σ

EUV Power



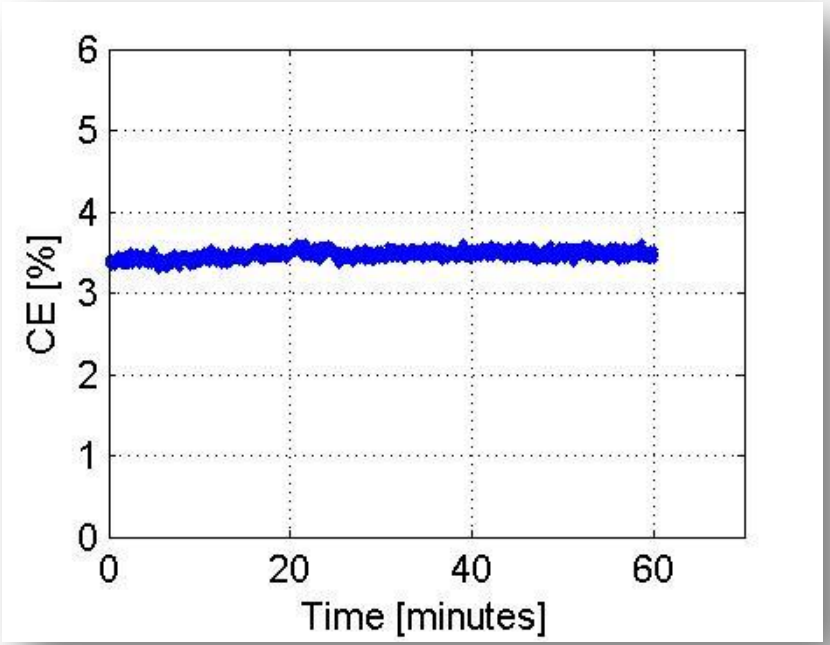


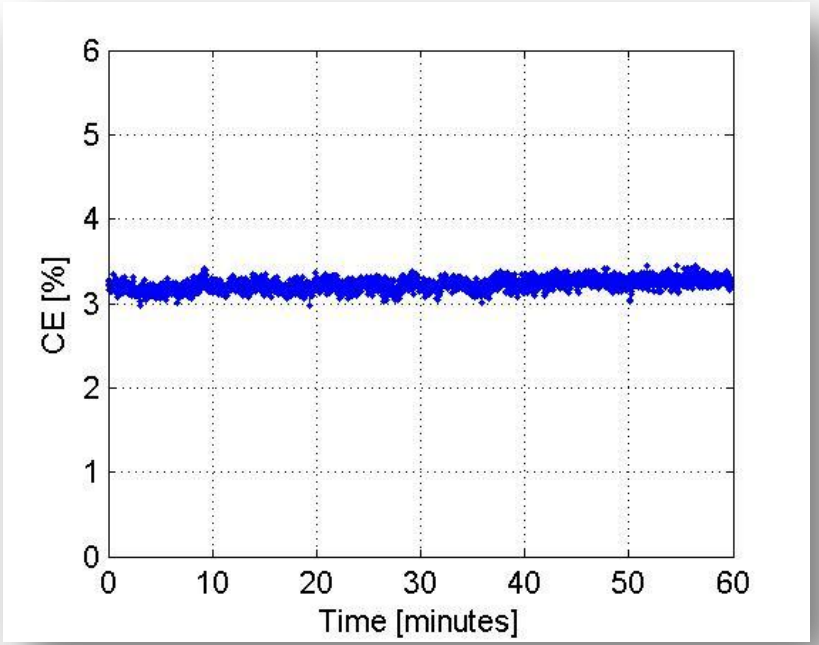
~80W

Data collected on Cymer 1, stand alone test source, NXE:3300B

Repeatable 80W one hour test runs

>3% Conversion Efficiency (CE) at 80W



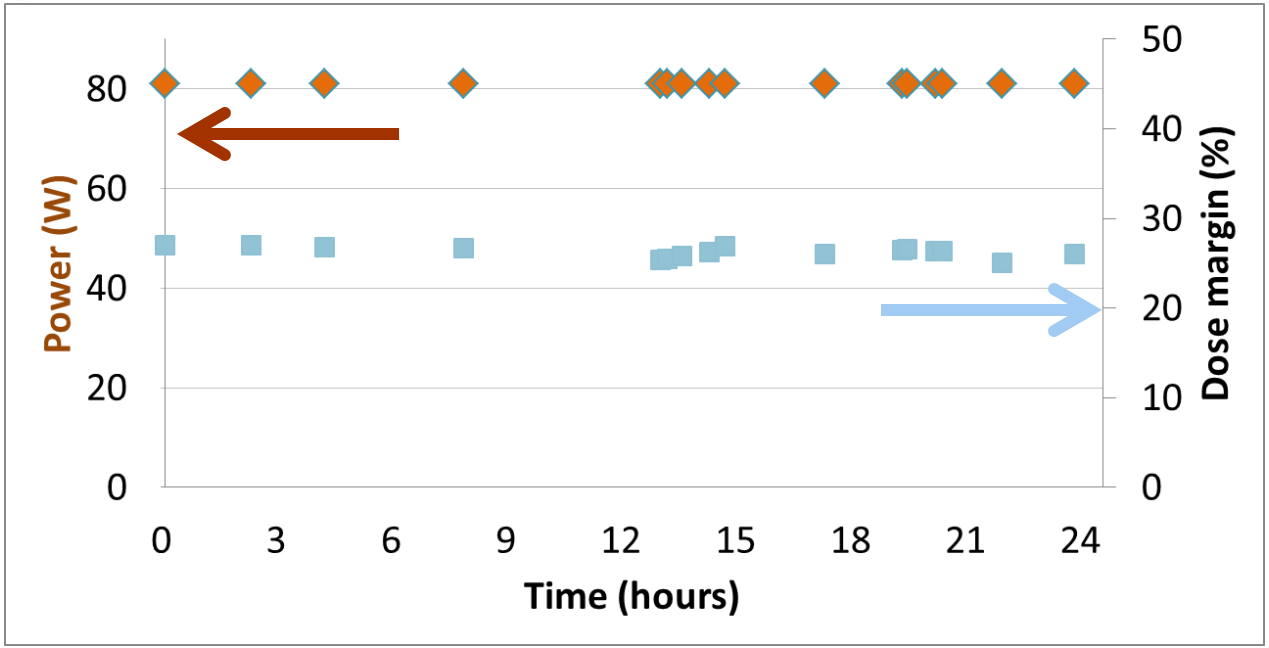


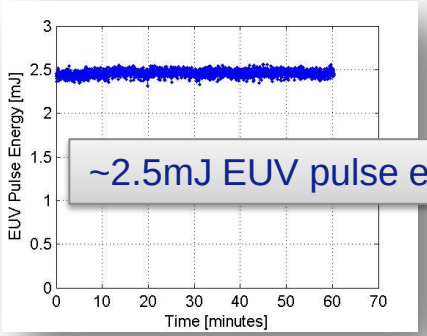
Multiple runs at 80W with >3% CE on NXE:3300B

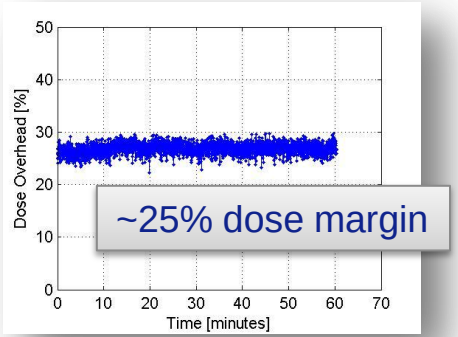
Data collected on Cymer 1, stand alone test source, NXE:3300B

Continuous Stable Source Operation at 80W

Execellent die yield, low dose margin







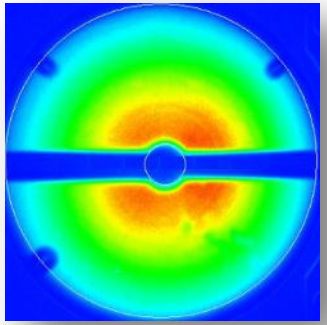
Continuous operation at 80Watts of EUV (good collector protection)

tsmc

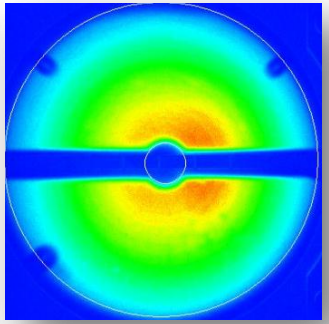
CYMER
An ASML company

NXE:3300B Collector Protection

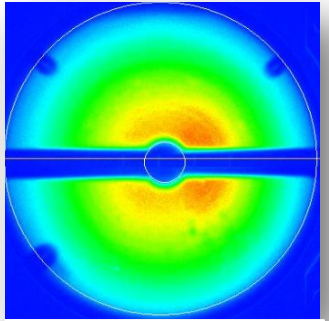
Configuration optimized to increase source availability and achieve >100Gp collector lifetime



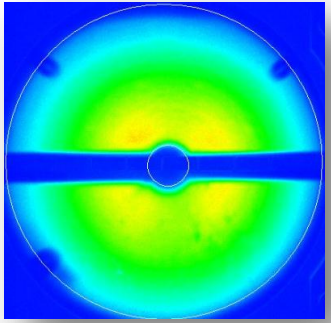
Initial image



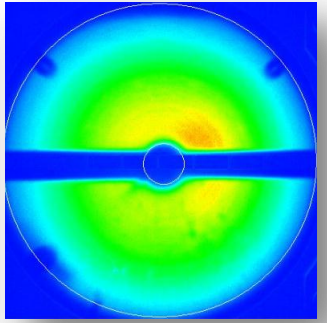
1.58 Gp



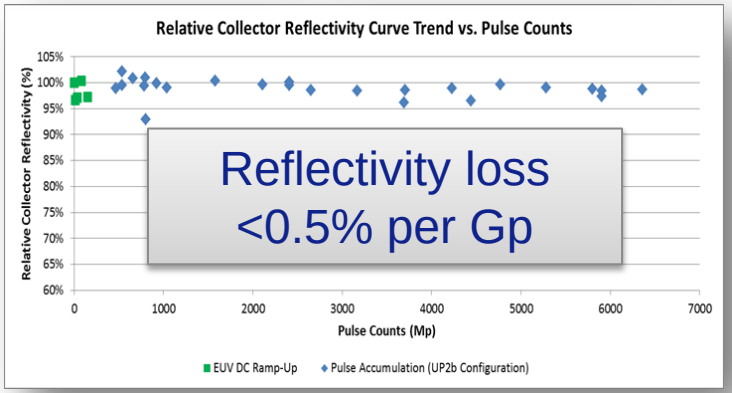
2.41 Gp



4.78 Gp



6.36 Gp



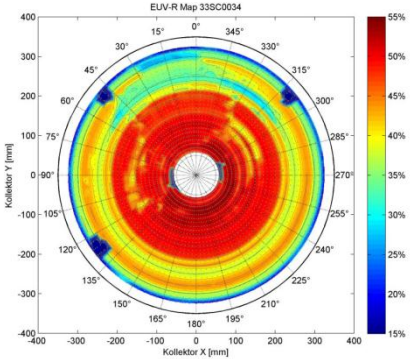
Improved Source Availability by eliminating a long maintenance procedure

Data collected on M1, stand alone test source, NXE:3300B

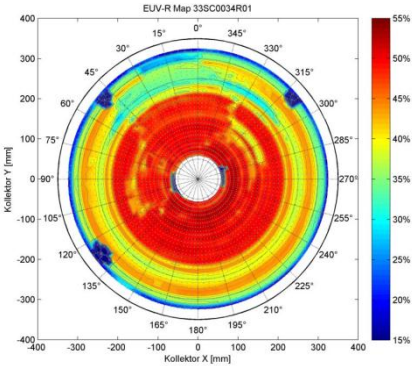
CYMER
An ASML company

In-situ Collector Cleaning Demonstration

Significant improvement to COO and Availability



As New



After Cleaning

- 'As New' Reflectivity restored with in-situ cleaning

In-situ collector cleaning capability demonstrated with NXE:3300B compatible configuration

Data collected on Cymer 0, stand alone test source for collector cleaning, NXE:3300B

Outline

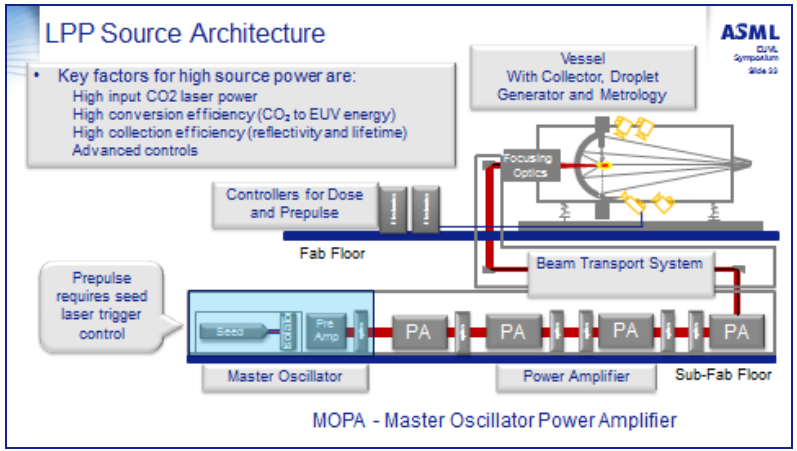
1. NXE:3300 source overview at customer Fabs
2. LPP Development in the Lab
3. EUV power scaling to 250W
4. Summary

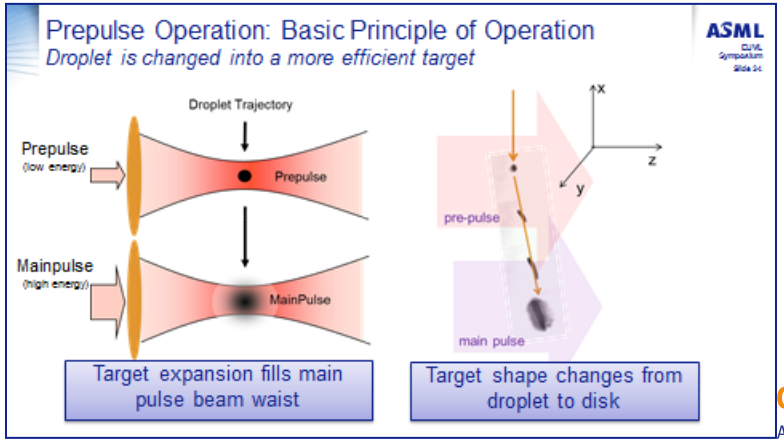
NXE:3300B Source power scaling to 250W

Key scaling parameters: laser power, CE, dose margin

Scaling parameter			
EUV Power in Burst (W)	40	80	**250**
Laser Power* (kW)	13	16	**27**
Conversion Efficiency (%)	2.5	3.5	**4.5**
Dose margin (%)	35	20	**10**

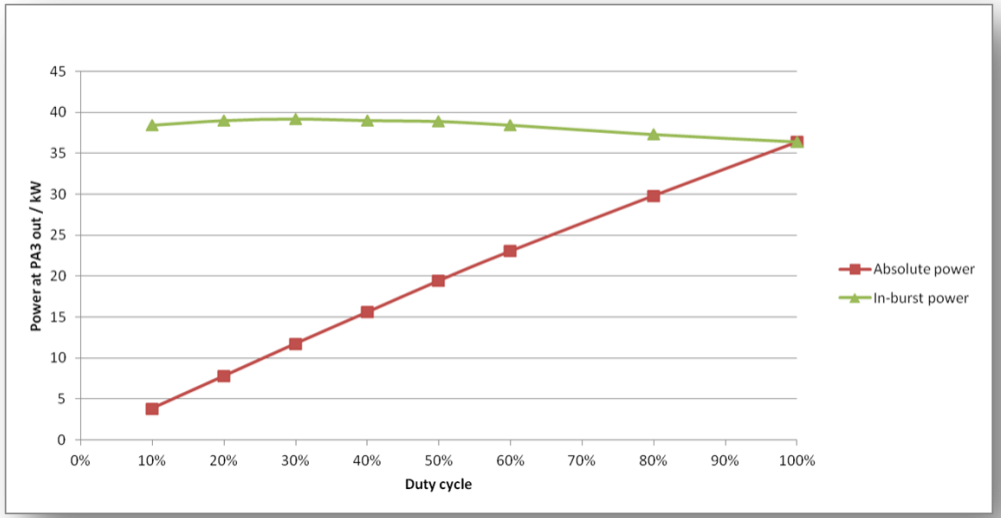
* MP on droplet

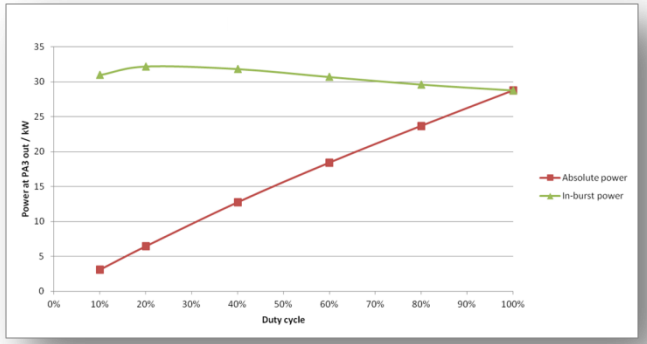


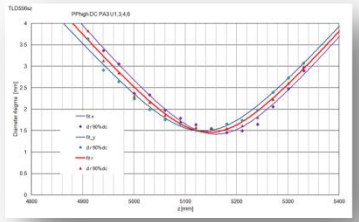


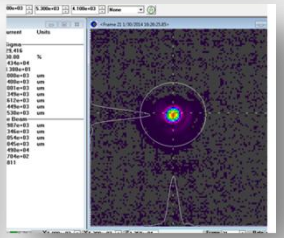
High Power Drive Laser (Power Amplifiers)

Supports roadmap requirements to get to 250W









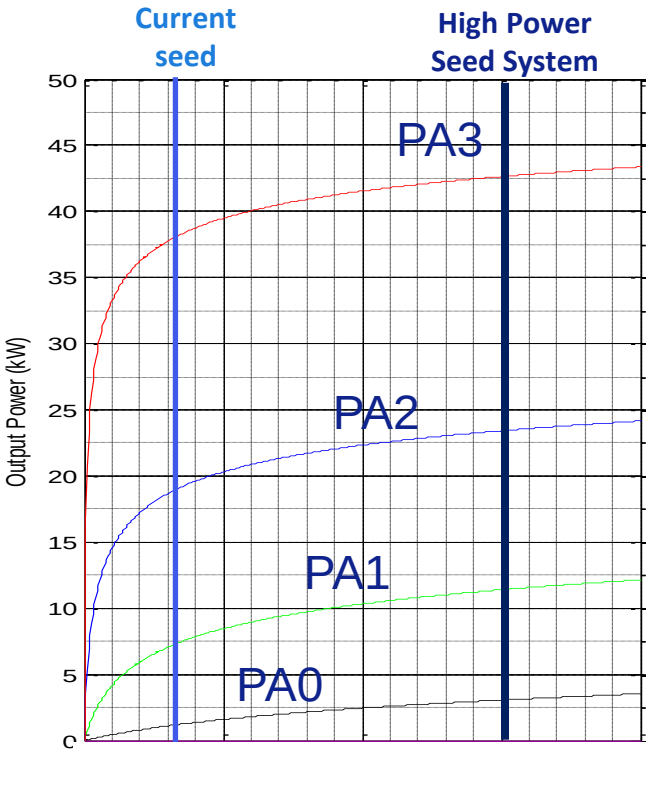
- **Stable power through duty cycle**
- **CO_2 power needed for 125 wph productivity**

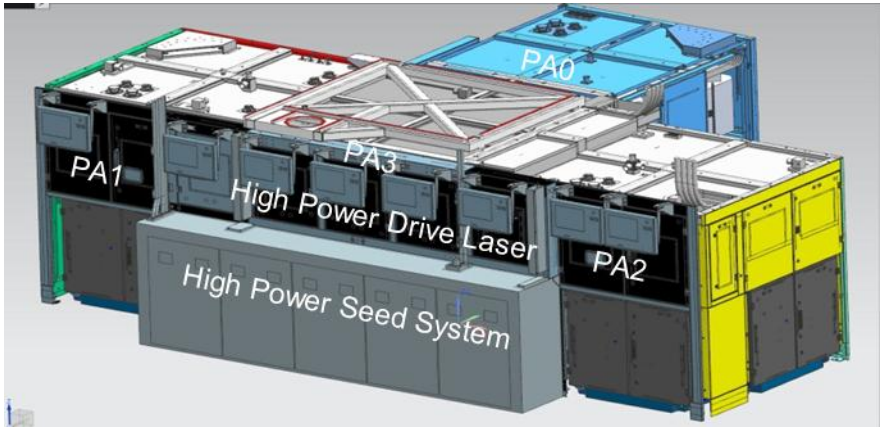
- Operation at 50kHz
- Good beam quality

Data collected at Trumpf

High Power Seed System (Master Oscillator)

High Power Drive Laser for 250W EUV



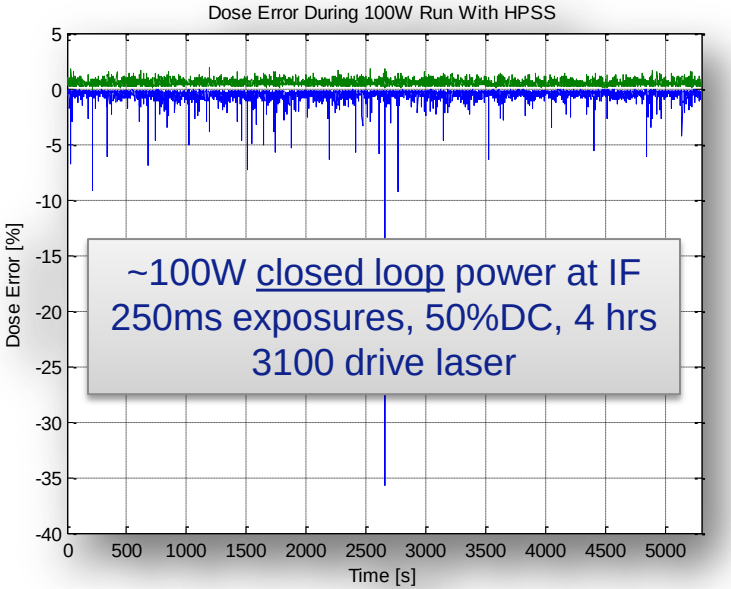


- Master Oscillator output power increased from
  - Better matched with the new high power drive laser
- Enables >40kW laser power

Data collected on Pilot 7 (MOPA Prepulse), stand alone test source, 3100 drive laser with Proto HPSS

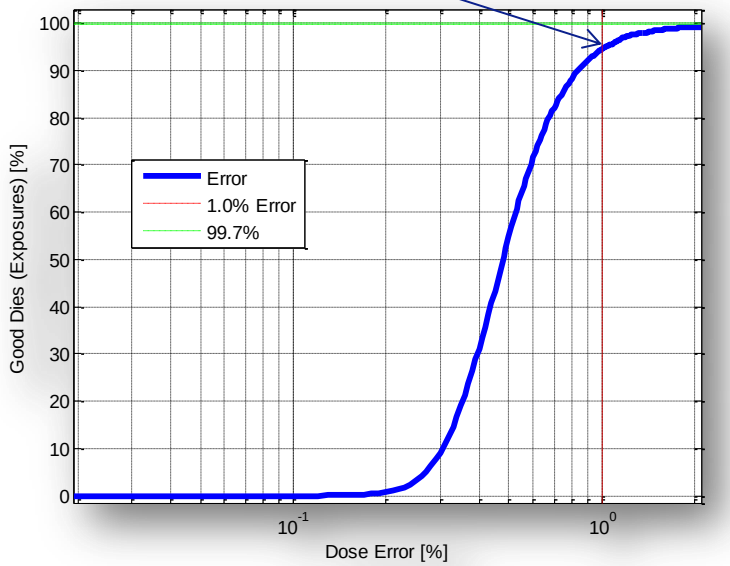
Stabilized High Output Power

Prototype High Power Seed System (HPSS)



~100W closed loop power at IF
250ms exposures, 50%DC, 4 hrs
3100 drive laser

~94% die yield
(25mJ resist assumed)

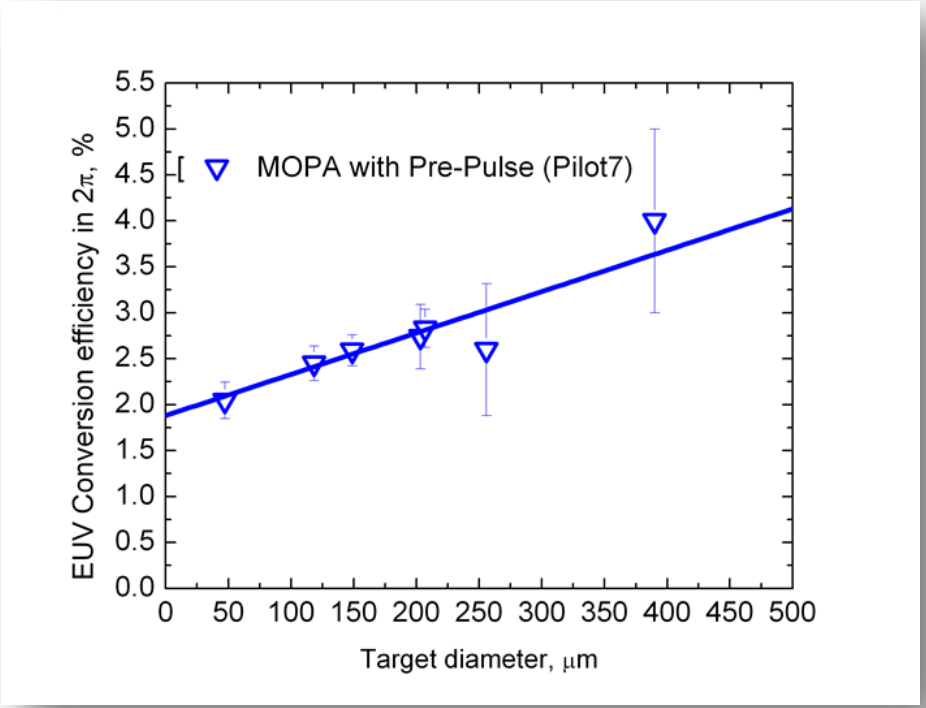


- **Highest per-pulse EUV energy successfully operated with dose control**

Data collected on Pilot 7 (MOPA Prepulse), stand alone test source, 3100 drive laser with Proto HPSS

Increased Conversion Efficiency

Enabled by optimized target shape and size



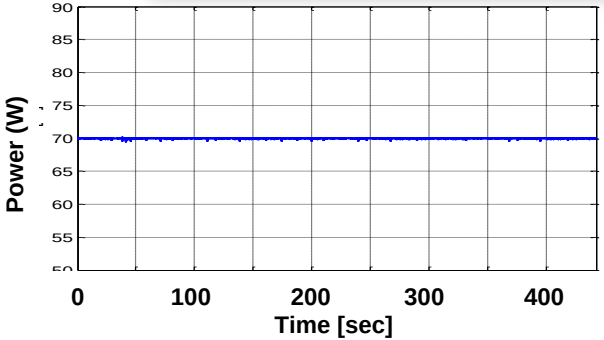
Data collected on Pilot 7 (MOPA Prepulse), stand alone test source, 3100 drive laser with proto HPSS

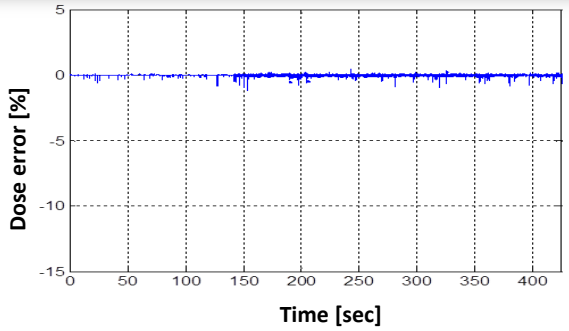
Prepulse changes the tin droplet into an optimized target shape leading to High CE

Advanced Controller Improves Dose Margin to <10%

Also increases power by 10%

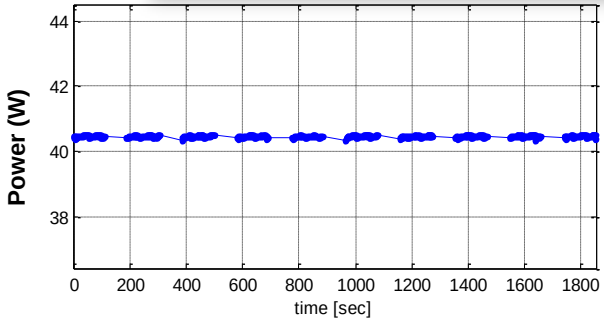
Advanced controller: 75W open loop power → 70W closed loop power

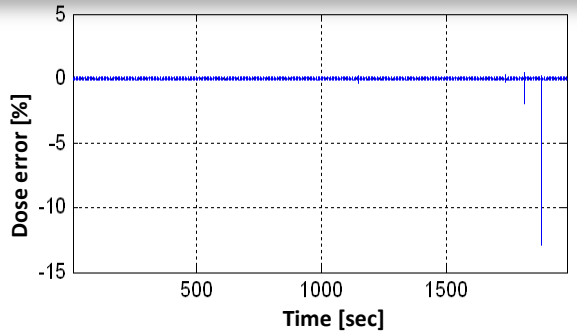




Advanced controller :
Higher open loop power due to improved CE
Good dose control at <10% dose margin

Current controller: 67W open loop power → 40W closed loop power





Data collected on Pilot 7 (MOPA Prepulse), stand alone test source, 3100 drive laser with proto HPSS

Current controller:
Good dose control at 40% dose margin

Outline

1. NXE:3300 source overview at customer Fabs
2. LPP Development in the Lab
3. EUV power scaling to 250W
4. Summary

Summary

- **Industrialization of NXE:3300B; sources installed and operating at customers**
  - Stable source operation allowing integration at chipmaker fabs
  - 500 wpd productivity in 2014
  - Collector lifetime >50 Gpulses
- **MOPA-Prepulse source technology demonstrated improvements**
  - 80W expose power, long runs, multiple sources
  - Collector lifetime demonstration extrapolates to >100Gp
- **In-situ collector cleaning technology demonstrated**
  - Improves both COO and Availability
- **Technology feasibility for 125 wph productivity demonstrated**
  - >35kW Drive Laser power demonstrated (27kW needed)
  - ~4% EUV conversion efficiency demonstrated
  - <10% dose margin demonstrated with advanced controls

Acknowledgements

Thank you!

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ASML